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ORGANIZED BIBLIOGRAPHY OF REFERENCES TO SOVIET STUDIES
ON VARIATION OF LATITUDE
AND
MOTION OF TERRESTRIAL POLES

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VARIATION OF LATITUDE PROBLEM AND
MOTION OF TERRESTRIAL POLES

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I. INTRODUCTION

Soviet positional astronomers and geodesists have expended considerable effort on the problem of the motion of the terrestrial poles and its effect on latitude variation. Since these fundamental studies are of possible significance to intercontinental geodetic ties and to those geodesists interested in problems of higher geodesy, preliminary analysis of Soviet work in this field was undertaken [REDACTED]

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Results of his

study are incorporated in Section II of this report.

Part II is a bibliographic reference guide to additional Soviet data dealing with this problem which were collected by the staff of this project during the course of its work on the primary objective of studying Soviet geodesy, photogrammetry and cartography. No attempt has been made to collect all available Soviet data dealing with variation of latitude.

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II. REPORT NO. 1

VARIATION OF LATITUDE PROBLEM

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I. An important summarizing article by K.A. Kulikov: "Motion of the Poles of the Earth and the Variation of Latitude" appeared in the Russian language, in Vyp. 5 of Uspekhi Astronomicheskikh Nauk (1950).

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See [REDACTED] Translation No. 6 for a complete translation of this article. Its importance consists chiefly in Fig. 9 which contains the motion of the pole, measured from Orlov's mean pole, for the entire interval 1891.5 to 1946.0.

Furthermore, we can infer the following:

a) The Russians have made no substantial progress, to date, in their effort to explain the observed effects. They attribute the annual term to changes of air mass, snow cover, pressure of the atmosphere, but make no attempt to compute the actual predicted amount of the "forced nutation." They believe that this term is substantially the same in all the years, but minor differences are not ruled out -- especially in regard to the duration of successive meteorological cycles.

b) The Chandler periodic term of 14 months, when freed from the observed variation through the process of subtracting from the latter the mean components of the annual, forced nutation leaves the almost pure effect of the "free nutation." This shows very large changes in amplitude, from 0!04 to 0!25 between 1892 and 1938. There are also suspected sudden changes

in phase, as in 1925. The motion of the pole produced by the free nutation is approximately a circle, whose radius varies. (The motion produced by the forced nutation is an ellipse with $e = 0.5$). No explanation of the change in the amplitude of the free nutation is suggested by the Soviets, except indirectly, by remarking that if a "rearrangement of the mass on the earth had happened only once and had then ceased" the free nutation would continue indefinitely with a constant set of elements. Thus, presumably, the variation of these elements suggests that the "rearrangement of the mass" is a continuing process.

c) There is no new information concerning the "non-polar" variation which Orlov has designated as ψ . Apparently, the reality of these quantities is not being questioned -- there is nowhere any suggestion that it might be caused by systematic errors of observations, except in those cases where the methods, the instruments, the observing program, or the entire latitude stations were changed. This non-polar variation which affects even nearby stations in different ways, is apparently not at present considered sufficiently well observed to warrant a thorough discussion. Thus Kulikov limits his remarks to a comparison of the ψ values at Carloforte and Greenwich, between 1917.0 and 1927.5, which had been previously given by Orlov. One is led to infer that different stations may "slip" toward, or away from, each other by amounts of the order of a few meters, at most.

II. It has seemed to me that there might exist a connection between the variation of latitude and the variation in the rate of the earth's rotation.

a) This latter problem has been greatly advanced, in recent years, through the researches of N. Stoyko in Paris. Taking advantage of a recent

trip to Europe (September, 1951) I secured a set of Stoyko's reprints, some of which are not often found in astronomical libraries. (Dr. Stoyko is a Russian who went to France after the revolution, having previously been a member of the anti-communist forces of Southern Russia. He is now the Chief of the Bureau de l'Heure.)

Stoyko's own principal contribution to the problem of the earth's rotation is his discovery of an annual (or seasonal) variation, which has been amply confirmed at other observatories. This annual term of the earth's rotation, found by comparing an accurate quartz clock with astronomical transits, is almost certainly directly connected with the forced nutation of the variation in latitude. The change of the pole results in an error of the observed transit amounting to

$$(\times \sin \lambda - y \cos \lambda) \operatorname{tg} \varphi$$

which may exceed 0.02 second for $\varphi = 50^\circ$ (Paris). The amplitude of Stoyko's seasonal term is about 0.06 second. Thus the latitude effect probably accounts for a substantial part, but not for all, of the Stoyko effect.

b) Stoyko, and more recently, D. Brouwer (Physics Today, 4, No. 8, 1951) have shown that, contrary to the views of earlier workers, (De Sitter, etc.) it is not the deviations from uniform rate of rotation of the earth, Ω , that undergo sudden changes, remaining linear between such epochs, but the derivatives of these deviations, $d\Omega/dt$, that behave in this manner. The most striking sudden changes in the observed values of $d\Omega/dt$, since the beginning of the latitude survey, occurred about in 1910: Stoyko's curve of the annual variation is shown on attached sheet.

If we compare this curve with the curve of amplitudes of Orlov's "free nutation," which I have very roughly extended beyond Orlov's last year, 1938,

using for this purpose the curves of the total variation given by Bulikov we have a suggestion of a correlation: large values of $d\Omega/dt$ correspond with large amplitudes of the free nutation.

It is impossible to go further at the present time. There are no reliable physical explanations of either of the two effects. But both undoubtedly result from a change of the moment of inertia of the earth.

It is also evident that there is no correlation between the amplitudes and the direct deviation as measured, for example, by the fluctuations of the longitudes of the noon.

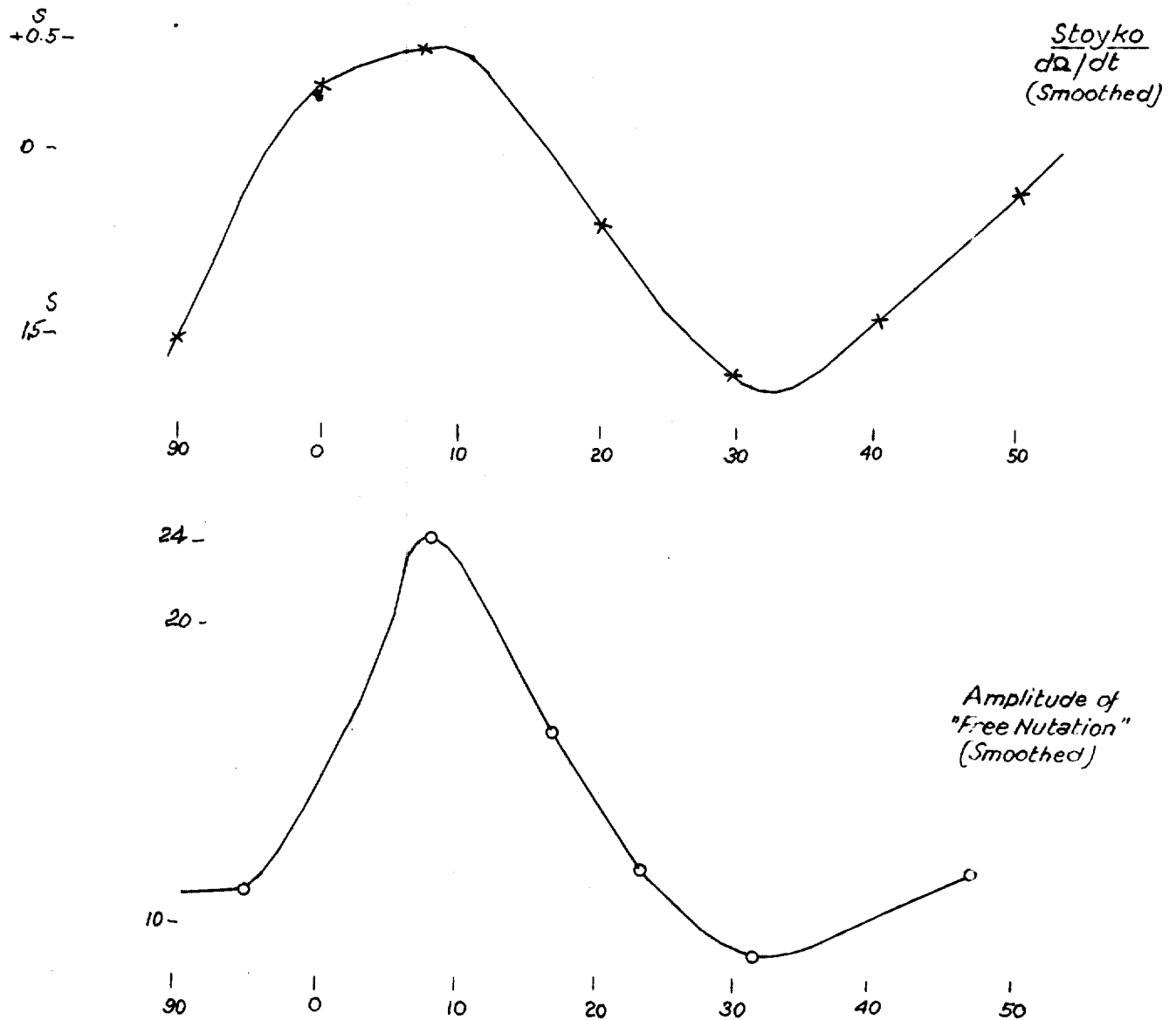
III. I have had extensive correspondence with a number of geophysicists concerning:

a) Annual periodic term of latitude variation (Munk, Mintz). Their opinion is that the present information on the meridional component of the winds is insufficient to enable them to attack this problem.

b) The same investigators, after having been reasonably confident in earlier papers that the winds could explain the annual (Stoyko) term of the earth's rotation, now state that the latest data will permit them to attribute only a small fraction of the Stoyko effect to the winds.

c) Dr. Byerly believes that there are definite slippages of parts of the earth's crust. These may explain the Ψ terms of Orlov. This problem requires further study, and I am not now prepared to report on it in detail.

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PART I.

MOTION OF THE TERRESTRIAL POLES

A. Trudy Poltavskoy Gravimetricheskoj Observatorii, vyp. 2, 1948.

1. E. P. Feodorov: Foundations of the Modern Theory of the Motion of the Terrestrial Poles, p. 3.

The model discussed in this paper had its beginning in Newton's Principia: the earth is considered as a sphere surrounded by a thin ring around the equator. The ratio of the mass of the ring to the mass of the planet is

$$\frac{m}{M} = \frac{2}{3} \frac{C - A}{C}$$

where $H = \frac{C - A}{C}$ is the mechanical polar flattening and equals 1/305. The variation of latitude can be demonstrated with the help of the ring model; it was in fact predicted by Newton, who did not, however, derive its period. For a rigid earth this was done by Euler: $T_0 = \frac{A}{C} \cdot \frac{1}{H}$. One of the principal tasks of the contemporary work on the variation of latitude is: to:
1) establish the general nature of the effects produced by the elasticity of the earth; 2) find the relation between the potential of the tide-producing force and the resulting deformation of the earth; 3) determine the changes in the shape of the earth in relation to the instantaneous axis of rotation.

If the rotation of the earth should be stopped, it would assume a new shape, not spherical because of its elastic properties, but one having H_n different from H .

If the rotation is resumed around a new axis, the earth will form a bulge along the equator of this new axis. There are thus two bulges, and on Newton's model two rings. The first is firmly attached to the globe and

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its mass is $m_A = \frac{2}{3} H_n$. The second wanders around because of the motion of the instantaneous axis. It causes no immediate effect upon the variation of the latitude. Approximately $T/T_0 = H/H_n$, but since $H > H_n$ we find that the elasticity increases the period.

There follows a discussion of the determination of H_n from observations of the tidal deformation of the earth.

The variations of the potential of the centrifugal force, resulting from the motion of the instantaneous axis, produce small oceanic tides with period T and this tends to dampen out the oscillation. This is analogous to the assumption that the second, movable ring in Newton's model experiences friction. Consequently, it no longer canals out in so far as its centrifugal acceleration is concerned. The amplitude of the oscillation of the axis must decrease. This raises the following question: What are the efforts that maintain the free oscillation of the poles?

The annual transport of mass on the surface of the earth produces a change in the location of the pole of inertia. This, according to Patau, is transferred with greatly increased amplitude to the pole of rotation.

Fig. 4 shows the migration of the poles of inertia caused by meteorological effects, according to 1) Jeffreys, 2) Schweydar, 3) Rosenhead, and 4) Byzova. In general they represent satisfactorily the observed poles of inertia, shows as crosses for January (bottom) and July (top). The main effect is due to the accumulation of air in winter over Europe and Asia.

The departures of these meteorological effects from strict periodicity probably are responsible for the maintenance of the free oscillations. They are enhanced by earthquakes and volcanic eruptions.

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The article closes with a brief discussion of the statistical method of G.Udny Yule and its application by Jeffreys.

2. N.A. Popov: Variation of the Latitude from Observations of Two Bright Zenith Stars, p. 21.
 3. E.V. Lavrentyeva: Observations of the Zenith Star β Draconis at Irkutsk, p. 42.
 4. S.V. Drosdov and E.P. Feodorov: Variations of the Latitude of Poltava in 1945.5 - 1946.5, p. 56.
 5. G.K. Zimmerman: New Discussion of the Observations made by I. Bonsdorff at Odessa in 1908-1910, p. 62.
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 7. E.P. Feodorov: Determination of the Pitch of a Micrometer from Observations of Pairs of Stars taken from the Washington Zenith Stars, p. 79.
 8. N.A. Popov: Gravimetric Connection between Poltava and Lvov, p. 84.
 9. Z.N. Aksentyeva: On the Tides of Lake Baikal, p. 106.
 10. Z.N. Ausentyeva: Results of an Eleven-Year Series of Observations (1930-41) of the variation of the Plumb Line at Poltava, p. 121.
- B. Trudy Poltavskoy Gravimetriceskoy Observatorii, Vyp. 3, 1950.
1. A.Ya. Orlov: The Gravimetric Observatory of the Ukrainian S.S.R. Academy of Sciences at Poltava, p. 3.
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 4. S.V. Drozdov: Determination of Declinations of Faint Stars with the Zenith Telescope, p. 121.
 5. E.P. Feodorov: On the Causes of Changes in the Inclination of the Axis and Azimuth of Meridian Instruments, p. 126.
 6. G.A. Freiberg-Kondratyev: Construction of Transit Instruments and Meridian Circles, p. 149.

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7. A.K. Korol: Motion of the Pole of the Earth from 1915.8 until 1929.0, p. 162.

- C. N.L. Byzova. On the Effect of the Transport of Air upon the Motion of the Axis of the Earth. Doklady, Akademiya Nauk, SSSR, T. 58, Vyp. 3, 1947

During the winter time there appears over Asia and Europe an additional mass of air, amounting to 3×10^{14} tons, while during the summer this mass flows toward the oceans. This has resulted in a diagram which shows the distribution of pressures in the form of lines, giving equal differences July minus January. These lines indicate a very large excess in central Asia and a minimum just east of the southern tip of Greenland.

- D. Astronomicheskii Zhurnal, T. 18, Vyp. 3, 1951.

- N.B. Divari: The Stellar Component of the Light of the Night Sky, p. 163.

Previous estimates based upon the star count of Seares and van Rhijn cannot be regarded as adequate. Hence, a surface photometer designed by V.G. Fessenkov was used in 1946 at Alma Ata and in 1949 near Lam Issyk-Kul. Special observations were made to determine the atmospheric and zodiacal light components. The unit of surface brightness used in most of the tables and formulae is one star of magnitude 5 per square degree. Table 1 shows $K(Z)$, the atmospheric component in the first approximation. These values are relative to the brightness at the pole. Table 4 gives the final data of $K(Z)$. As a first approximation at the pole $K(Z) = 0.38$ unit. Table 2 gives the first approximation of $L(\beta)$, the stellar component. Table 3 is the computed scattered stellar light $GR(Z, \beta)$ where the transmission coefficient $p = 0.86$. The second approximation of the direct star light $L(\beta, \lambda)$ II is in Table 5. The final atmospheric component $Z(b)$ is in Table 7 (Fig. 2). Table 9 contains a comparison of different sets of values of $L(\beta)$.

Successive lines are 1) Van Rhijn; 2) Yntema; 3) Gron .27; 4) Gron 18; 5) Gron. 43 fotogr.; 6) Pesenkov from star counts by Sears; 7) Divari. The left upper corner of each rectangle gives $L(\rho)$ in the absolute unit used by the author. The right, lower corner gives relative values, reduced to $L(90^\circ) = 1.0$. The light of all stars fainter than 6.5 mag. is equal to 600 stars of mag. 1. Adding to this 176 stars brighter than mag. 1, we have a total of 776 stars.

E. Astronomicheskiy Zhurnal SSSR, T.8, Vyp. 5, 1951

V.V. Sharnov: Photometric Comparison of Twilight Effects on the Earth and on Venus, p. 382.

An attempt is made to compare the brightness of twilight on Venus with that on the earth. On the latter the logarithm of the brightness varies linearly with the angle D from the terminator. The observed brightness consists of two components B_a (atmosphere illuminated by the sun) and B_p (surface of the ground illuminated by twilight). The latter is $B_1 = rpE$ where r is the coefficient of reflectivity of the surface, p , is the transmission coefficient and E is the illumination produced by twilight.

The author has observed: a) the sky at the zenith B_z , and b) a white horizontal surface B_e . He then determines $\mathcal{K} = r_e \frac{B_z}{B_e}$ and finds $\mathcal{K} = 0.55$, independently of D . Since approximately $B_z = B_a = \mathcal{K} E$ he finds that from a distant point the surface brightness of the twilight zone of the earth would be $B = B_p + B_a = (pr + \mathcal{K})E$. E is in lux, B in spotilbs. From observations made in 1934, he found that for $3^\circ < D < 12^\circ$ the following relation holds $\log E = \alpha - \gamma D$ where α varies greatly with the conditions but γ remains constant. This is equivalent to $\log D = \beta - \gamma D$. If the density is given by $\rho = \rho_0 e^{-\beta h}$, then there should exist the relation $\gamma = \text{const. } \beta R$. Consequently, for the earth and Venus:

$$\beta_E/\beta_V = \frac{\gamma_E R_V}{\gamma_V R_E}$$

Table 1 gives the observations for the earth. They show that the surface brightness even quite close to the terminator ($D = 3^\circ$) is only about 0.002 to 0.004 of the brightness of the illuminated disc. Hence, the observational difficulties are immense.

Nevertheless, Sharonov gives in Table 2 the results of two photographic series of observations of Venus made with a 15-inch refractor (the original negatives were destroyed during the war at Pulkovo). Here d is the distance from the center of the planet, E is the angle of reflection, i the angle of incidence. B is measured along the equator. The results are given in the form of $\gamma = 0.114$ and also as the gradient of the brightness at the terminator itself, which is designated as $G_0 = 0.051$. For the earth $\gamma = 0.44$; $G_0 = 0.22$. This would indicate that on Venus the twilight effects are about 3 to 4 times stronger than on the earth. But photographic spreading, etc. would tend to vitiate this result, and the author believes that the real ratio is about 2.

F. E.V. Pyaskovskaya Fesenkova. Relation between Scattering of Light in the Atmosphere and the Wave Length. Doklady, Akademiya Nauk SSSR, T.80, Vyp. 4, 1951

The sizes of the particles in the atmosphere of the earth vary with the angle θ and the results are shown for three days. The index $n =$ about 1 at $\theta = 10^\circ$, and 3.5 at $\theta = 120^\circ$. The case $n = 4$ is Rayleigh's law. The observations were made with a photoelectric cell at Alma-Ata.

G. S.I. Sivkov. On the Coefficient of Transparency of the Atmosphere. Doklady, Akademiya Nauk SSSR, T.80, Vyp. 4, 1951.

The purpose was to compute the total solar radiation during a cloudless day, per square centimeter.

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